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What comes first? Social strength or common friends?

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A famous result in social network theory is the *weak ties hypothesis* by Mark Granovetter by which the strength of a social ties correlates with the social embeddedness of the tie. Strong ties are surrounding by common friends, while weak ties happen between communities. Although this hypothesis was confirmed in a number of online and offline networks, little is know about how this correlation is built and/or destroyed in time, that is, how common friends and tie strength evolve together when a tie is created or destroyed. By analyzing the mobile phone communication network of about 20 million people over a long period of time of 19 months, we found that once that a tie is created is reaches almost instantaneously its strength while its embeddedness slowly growths even months after tie formation. The opposite is find when a tie is destroyed: tie strength last until the very last minute although common friends started to disappear months before. Our results highlight that the Granovetter *weak ties hypothesis* is a dynamical process that happen at a very slow time scale, showing the intricate evolutionary dynamics of network interactions and structure. .

Understanding the very dynamics which regulates the process of why an individual decides to add or remove a social tie is a very complex process which has been of interest of many studies [1, 4–6]. However, since tie creation/removal processes alter the structure of the network in which the individual participates, we may wonder whether changes in the topology of the local network surrounding a tie can tell us something about the fact that a new connection is going to appear or has just been removed. In particular, what we want to answer here is: to what extent individuals choice to create a new tie is related to the their social network before the new connection has been created? Does the topology of their network change after the establishment of a new tie? The same questions can be applied when a connection is removed, instead than created.

To address this we first introduce a new methodology to investigate temporal networks [7], an issue which is convoluted with the way social networks are observed and modeled, and which has been recently been pointed out as a problem in the field of social networks [8]. By means of this methodology we are able to disentangle tie activation/deactivation from their bursty activity. This method allows us to determine, for each tie in our dataset, the set of their common neighbors that are active at any time instant. Moreover, for any given tie, we can identify with high precision the time at which it has been created or destroyed.

As mentioned before, we are interested in understanding whether changes in the local topology are related to the creation/removal of a new/old social connection. For this reason, for each of these two categories of ties, we study the evolution of the topological overlap in a time window which spans a period going from before to after the tie has been created or removed. Accordingly to the weak tie hypothesis, ties between individuals who have many common friends (large overlap), are stronger than the ones between people which few common friends (small overlap), who instead act as bridges between different tight groups Since our analysis allows us to assess when a tie has been created or removed and, at the same time, to analyze the instantaneous contact network, we take advantage of this and try to investigate the *dynamical Granovetter effect*. Specifically, we also separate the ties in different groups according to their strength (total number of calls during the whole 19 months period) and we analyze the temporal evolution of their neighboorhood overlap for each of these groups. For comparison, we also show the average overlap between pairs of nodes randomly chosen from the whole population, and the average overlap of ties that do not form or decay within the observation window.

Our contribution shows a number of important results. According to the weak ties hypothesis (see figure 1), we observe that topological overlap is strictly related to the intensity or weight of a social relation, meaning that the stronger is the relationship between two persons, the more friends they have in common, in line with previous results [1, 2]. Moreover, the overlap between two individuals who form (remove) a connection at some time during their lifetime, is significantly higher than the one observed between any random pair of individuals in the whole population months before (after) the link has been established (removed). This constitutes a more clear evidence of why the topological overlap is usually a very good feature in the prediction of tie creation [3, 9, 10].

More interestingly, we find that the process that drives two individuals to link together is highly dynamical and that, locally, it entails the change of the underlying topology of the network. We observe, in fact, a large overlap many days before the connection has been established,

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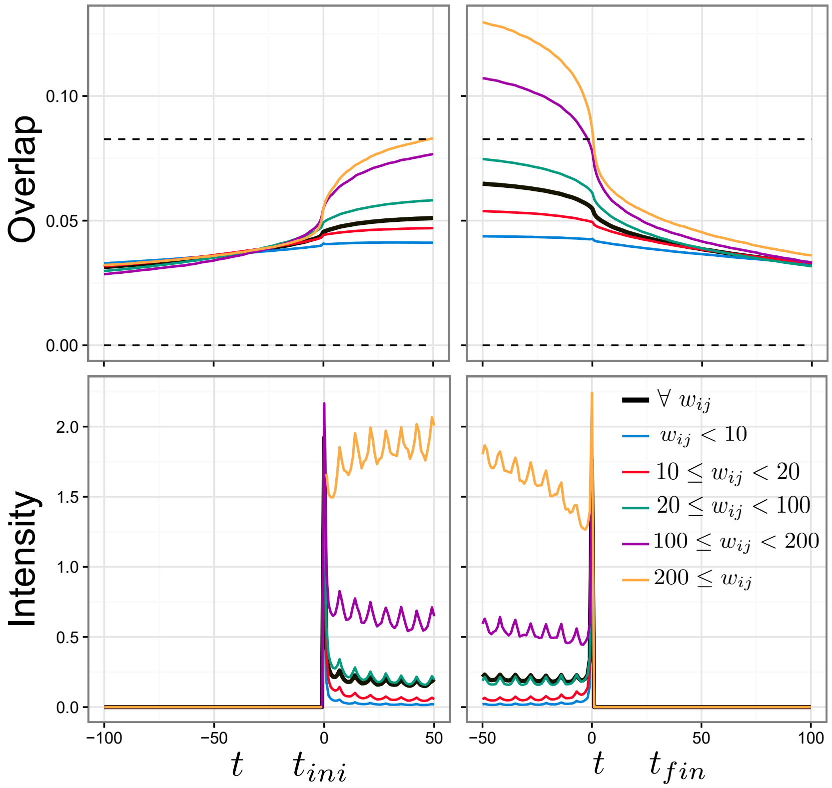

FIG. 1. Co-evolution of the topological overlap (Jaccard coefficient, top) and intensity of communications (number of calls per day, bottom) before and after the creation (left) and destruction of a link (right) for different intensity of the links. Dashed lines in the top panel correspond to the average overlap of two randomly selected nodes in the newtork (bottom) and the average overlap for all the links in the network.

and it continues to increase over time after the tie forms. A similar result is found when a tie is removed: the topological overlap between two individuals starts to decrease much before the connection is removed and it keeps decreasing in time after the breakage, although very slowly. This allows us to reply to the following question: what comes first, tie strength or common neighbors? Our results indicate that the connection comes first, and only after the correlation between tie strength and topological overlap starts to form, suggesting indeed a sort of dynamical Granovetter effect that, to the best of our knowledge, has not been investigated before.

These results indicate that the properties of the local network between two individuals contain important information about their relationship even if no interaction between them is observed. They also have outstanding interest from a sociological and anthropological point of view since they shed more light on the way in which humans establish and remove social connections. We have seen, in fact, that the Granovetter effect is not just a correlation observed in the aggregated contact network, but a dynamical process that happens at a very slow time scale. The correlation between the number of common friends between two individuals and their strength is in fact observable within a time period significantly longer than the lifetime of the social relationship and acts as a "fingerprint" of the social relation itself.

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